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the Quality Index in

HARDWOOD SAWTIMBER MANAGEMENT

January
1956

PURDUE UNIVERSITY

Agricultural Experiment Station, Lafayette, Indiana

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Allyn M. Herrick

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The Quality Index in Hardwood Sawtimber Management

A. M. Herrick • Department of Forestry and Conservation

I. Introduction

The quality index concept was introduced by Herrick (1946a) in connection with a study of the lumber grades sawed from hardwood logs in Indiana. Rather than having to recognize and manipulate four or more standard lumber grades in dealing with the yields of logs and trees, the quality index defines their value, relative to that of some basic product, as a single number.

The most nearly basic application of the quality index, hereinafter referred to as the QI, is in connection with value determinations of logs and trees. For the purpose of establishing a system of log grades or tree-quality classes the QI is invaluable. It is almost a requisite in making interpretations when these log- or tree-grading systems are applied toward economic, silvicultural, or other ends. Also the QI concept is helpful in describing lumber quality in an accounting sense. The "single-number efficiency" of the index makes it extremely useful in comparing different lots of lumber and also in applying the principles of quality control.

Grade Yields and Lumber Values

Perhaps the most simple method of introducing and explaining the QI is through a numerical example. Consider two red oak logs that have been sawed into one-inch lumber. The lumber obtained from these logs will be of several different grades. The amounts of lumber, by grade, for each log, might be as shown in Columns 3 and 5 of Table 1. The large proportion of lumber from Log A that graded FAS or Selects shows this log was of higher quality than Log B. The influence of this higher quality together with its larger size becomes more evident when the value of the lumber in Log A is compared with that of Log B. Column 2 of Table 1 shows the prices per thousand board feet of the various grades of red oak on the Northern Market[1] as quoted in the Hardwood Market Report for April 10, 1954. These prices, when multiplied by the corresponding volumes, show the values of the lumber by grades. The total value of the lumber in Log A under this price situation is computed to be $42.90 compared to $21.40 for that in Log B.

TABLE 1. Calculation of the Lumber Values of Two Logs Using Price Data.

Lumber Grade	Price ($ per M)	Log A		Log B	
		Lbr. Vol. (bd. ft.)	Value ($)	Lbr. Vol. (bd. ft.)	Value ($)
(1)	(2)	(3)	(4)	(5)	(6)
FAS	186	120	22.32	20	3.72
Selects	166	60	9.96	20	3.32
No. 1C	126	45	5.67	60	7.56
No. 2C	78	30	2.34	50	3.90
No. 3C	58	45	2.61	50	2.90
Total	...	300	42.90	200	21.40

Price Relatives in Place of Dollar Prices

The type of evaluation shown in Table 1 becomes very time-consuming when it is made to include a great many logs, several different species, more than one marketing area, or prices for varying points in time. The first of several time-saving steps in computing the values of different kinds of lumber is to express the prices of the various grades as ratios, using one of the lumber grades as the base or reference grade. When No. 1C is the reference grade, the price ratios or **price relatives** for red oak would be as shown in Column 3 of Table 2. Price relatives, or p.r.'s as they are called herein, are merely

TABLE 2. The Use of Price Relatives in the Calculation of the Lumber Values of Two Logs.

Lumber Grade	Price ($ per M)	p. r. (ratio to 1C)	Log A		Log B	
			(bd. ft.) Lbr. Vol.	Rel. Val. (wtd. ratio)	Lbr. Vol. (bd. ft.)	Rel. Val. (wtd. ratio)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
FAS	186	1.476	120	177.12	20	29.52
Selects	166	1.317	60	79.02	20	26.34
No. 1C	126	1.000	45	45.00	60	60.00
No. 2C	78	0.619	30	18.57	50	30.95
No. 3C	58	0.460	45	20.70	50	23.00
Total	...	....	300	340.41	200	169.81

[1] F.o.b. mill point, Wausau, Wisconsin area.

ratios that may be used in place of dollar prices. The p.r.'s in Table 2 are weighted by the appropriate volumes in the various grades and the cross-products are summed for each log. These totals may then be used to estimate the lumber values as follows:

for Log A — 340.41 × \$126 ÷ 1,000 = \$42.89
for Log B — 169.81 × \$126 ÷ 1,000 = \$21.40

The error of one cent in the lumber value of Log A is due to rounding off the p.r.'s.

The Case for Standard Price Relatives

The p.r.'s used in Table 2 were true only for red oak on the Northern Market on the quotation of April 10, 1954 since this is the source of the price data from which they were computed. If p.r.'s had to be computed for each species, each marketing area and each new set of lumber prices, they would offer no advantage over actual prices. However, extensive studies by Ellertsen and Lane (1953) and by Beazley and Herrick (1954) have shown that in spite of the different monetary values placed on lumber for various reasons, the relationship that exists among the prices of the several grades of lumber is a fairly stable one. This stability permits the use of p.r.'s in place of fluctuating dollar prices and guarantees the utility of the quality index concept.

In their study, Beazley and Herrick (1954) show that individual p.r.'s are influenced by species and by marketing areas, but that they are relatively independent of time. Twenty-two mean p.r.'s reported for the FAS grade ranged from 1.211 for soft maple on the Southern Market[2] to 1.607 for hard maple on the Boston Market from July 5, 1947 to October 7, 1950. The standard errors of the individual means, however, were less than 0.025 in all but two instances, indicating that individual p.r.'s do not change very much through time. Even though some species p.r.'s are significantly different (from a statistical point-of-view) in a given marketing area, there is opportunity and need for using standard p.r.'s in calculating quality indices.

When QI's are used for estimating stumpage values or for other predictive purposes, the many opportunities for error must be appreciated. Measurement errors of dimension and grade in the tree itself, errors in forecasting the costs of conversion from tree to mill, inherent variability of lumber grade yields and, finally imperfections in the lumber market, all may contribute to a result of low reliability. Thus, if standard p.r.'s are used for all species in computing QI's the inexactnesses are not likely to importantly affect the accuracy of the values resulting from the use of such QI's.

The set of standard p.r.'s listed in Column 2 of Table 3 was adapted from prices that obtained on a free market in recent years, using 4/4 (one inch), plain-sawed, No. 1C lumber as the reference thickness and grade. For example, FAS lumber prices were found to average about 1.4 times as much as the No. 1C prices over a wide range of conditions of time, species, marketing areas and types of market. These p.r.'s are proposed for use with any hardwood species and for any of the hardwood markets in the Central States area.[3] Acceptance of such standard p.r.'s requires that the user be willing to sacrifice some precision, probably, in the interest of simplicity.

TABLE 3. Computation of the Quality Index for Two Logs.

Lumber Grade	Price Relative	Log A		Log B	
		Lbr. Vol. (% of tot.)	Col. 2 x Col. 3	Lbr. Vol. (% of tot.)	Col. 2 x Col. 5
(1)	(2)	(3)	(4)	(5)	(6)
FAS	1.4	40	56	10	14
Selects	1.3	20	26	10	13
No. 1C	1.0	15	15	30	30
No. 2C	0.6	10	6	25	15
No. 3C	0.4	15	6	25	10
Total	...	100	109	100	82

Quality Index Combines Relative Lumber Yields with p. r.'s

The QI is a single number that expresses the value of the lumber in a log or a tree as a percentage of the value of an equal volume of lumber of the reference grade. It may be expressed in formula form as:

$$QI = (\%\ FAS)\ (p.r._{FAS}) + (\%\ Sel.)\ (p.r._{Sel.}) + \ldots + (\%\ No.\ 3C)\ (p.r._{No.\ 3C})$$

wherein — "% FAS" means the percentage of the total volume grading FAS, and "$p.r._{FAS}$" means the standard price relative for FAS grade lumber, etc.

The calculation of the QI's for Log A and Log B is shown in Table 3. The products of the standard p.r.'s and the respective percentage grade yields are summed in Column 4, for Log A, and in Column 6, for Log B. These sums, 109 for Log A and 82 for Log B, are the QI's of these two logs. They mean that the lumber in

[2] F.o.b. Texas and Louisiana mills.

[3] Notice how they approach those computed in Table 2 for red oak on the Northern Market.

Log A is worth 109 percent and that in Log B is worth 82 percent as much as an equal volume of No. 1C lumber of the same species. Using the aforementioned price for No. 1C red oak lumber, the lumber in Log A would be estimated to be worth:

(1.09) (0.3 M bd. ft.) ($126 per M) = $41.20

and that in Log B would figure to be worth:

(0.82) (0.2 M bd. ft.) ($126 per M) = $20.66

These figures underestimate the true values, calculated before, by about 4 percent for Log A and about 3 percent for Log B due to the fact that the standard p.r.'s are consistently below those specific for the prices given in Tables 1 and 2.[4] Such discrepancies are to be expected when QI's are calculated for just a few logs, for an atypical species, or for an unusual market situation. Even in this illustration the errors are not disproportionately large if the unreliability in forecasting lumber grade recoveries is recognized and appreciated.

Table 3 emphasizes the fact that the QI is determined solely from price relatives and percentage grade yields. Thus the QI is a percentage that permits a quantitative comparison of logs, trees, or lots of lumber on the basis of the amount and value of lumber they contain. **Only the volume and the current price of No. 1C lumber need be ascertained to convert QI's to dollars.** If Log A were of some species whose No. 1C lumber sold for $80 per M bd. ft., its QI would still be 109 percent, but the lumber it contains would only be worth

(1.09) (0.3 M bd. ft.) ($80 per M) = $26.16,

or, if its volume were 400 board feet instead of 300, its lumber content would be worth

(1.09) (0.4 M bd. ft.) ($80 per M) = $34.88.

Though QI's are readily convertible to dollars, they are chiefly useful for making objective comparisons of quality, quite apart from monetary determinations.

Applications of the QI Are Increasing

The general utility of the QI has broadened greatly in recent years and new uses will continue to be made of it as the concept becomes familiar to more investigators. From the original assignment of the QI to describe the "average quality yields" of logs of various kinds and sizes, it was only a natural step to use QI's in the development of a set of log grades. The combined grades of the logs in a standing tree provide a tree grade, of a sort, that gives an indication of the QI of the tree as a whole. From a set of tree grades that are keyed to QI figures, it is thus possible to determine the gross lumber value of a tree, and even its conversion surplus.[5] As in determining the value of lumber in a log, QI multiplied by volume (from a volume table) multiplied by the selling price of No. 1C lumber equals the price of the lumber in the tree. When conversion costs have been deducted the conversion surplus for the tree is obtained. This latter is closely related to stumpage value. Stumpage values are ordinarily of interest in timber appraisal work, but herein they have been integrated with growth data as well, in developing a system for marking timber on the basis of value increment. Without the QI as a medium for describing quality and relative value many of these accomplishments would have been difficult if not impossible of attainment.

Background for the Present Study

In the original work that developed the QI idea (Herrick, 1946a) the price relatives were based upon FAS as the reference grade. As other research workers adopted the concept, other lumber grades were used as bases for the p.r.'s; by 1952 no fewer than five research reports, incorporating the use of three different base grades had made their appearance in the literature. For this reason a symposium on "A Standard Quality Index for Hardwoods" was held at Purdue University in October, 1952, in an attempt to standardize the index. Attendants agreed that the accepted reference base for the QI would be 4/4, plain-sawed, No. 1C lumber. (Purdue University, 1953.)

Log and lumber grade yield data that are used in this bulletin were collected in 1943, 1944 and 1950 at 14 different Indiana sawmills. In other form these data have been reported by Herrick (1946a) and McCoy (1952). The present publication combines and presents for the

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4 Actually the standard p.r.'s suggested herein will nearly always yield a QI that is conservative (too low). This is because the FAS p.r., 1.4, is somewhat low for the typical "grade lumber markets" and because Selects lumber has been pooled with the No. 1 Common grade in calculating the QI's (See page 6). The standard p.r.'s are meant to apply to lower priced markets and less valuable species as well as those for which price quotations are published.

5 "The surplus of sale value over the direct (variable) costs of conversion, exclusive of fixed charges." Guttenberg and Duerr (1949).

first time all available lumber grade yield information for Indiana and the corresponding QI's figured on the No. 1C base. In keeping with the 1946 study, Selects lumber has herein been pooled with the No. 1C grade.

From these basic data are developed tables of QI's and conversion surpluses for trees of different sizes and grades. These are subsequently used in timber appraisal and timber marking applications. Also reported herein is a novel means of value increment determination, given the growth rate.

The amount and extent of basic data analyzed herein are tabulated in Appendix C. Lumber yields were tallied for a total of 1,149 logs of 16 species or species groups. Red oaks, beech, sugar maple, white elm, and yellow poplar each contributed more than eight percent of the total volume and together they accounted for 80 percent of the total. Log diameters ranged from 7 inches to 32 inches, but 88 percent of the logs were between 10 and 20 inches in d.i.b. The Purdue log grades[6] were used to sort the logs into quality classes. Each of the four grades made up more than 22 percent, but less than 28 percent, of the total volume studied, hence all grades were well represented.

[6] See Appendix B for a description.

II. Useful Forms of QI Data

Lumber Grade Yields from Sawlogs and Their Corresponding QI's

The first result of a lumber grade recovery study is always a statement of the volumes of lumber, according to standard lumber grades, that were sawed from logs of various descriptions. Even what appear to be identical logs, however, seldom yield identical total amounts of lumber. Thus absolute lumber grade yields are almost always converted to percentages in order to make them apply more generally.

But nice descriptions of quality among logs of different sorts are impossible, even in terms of percentage

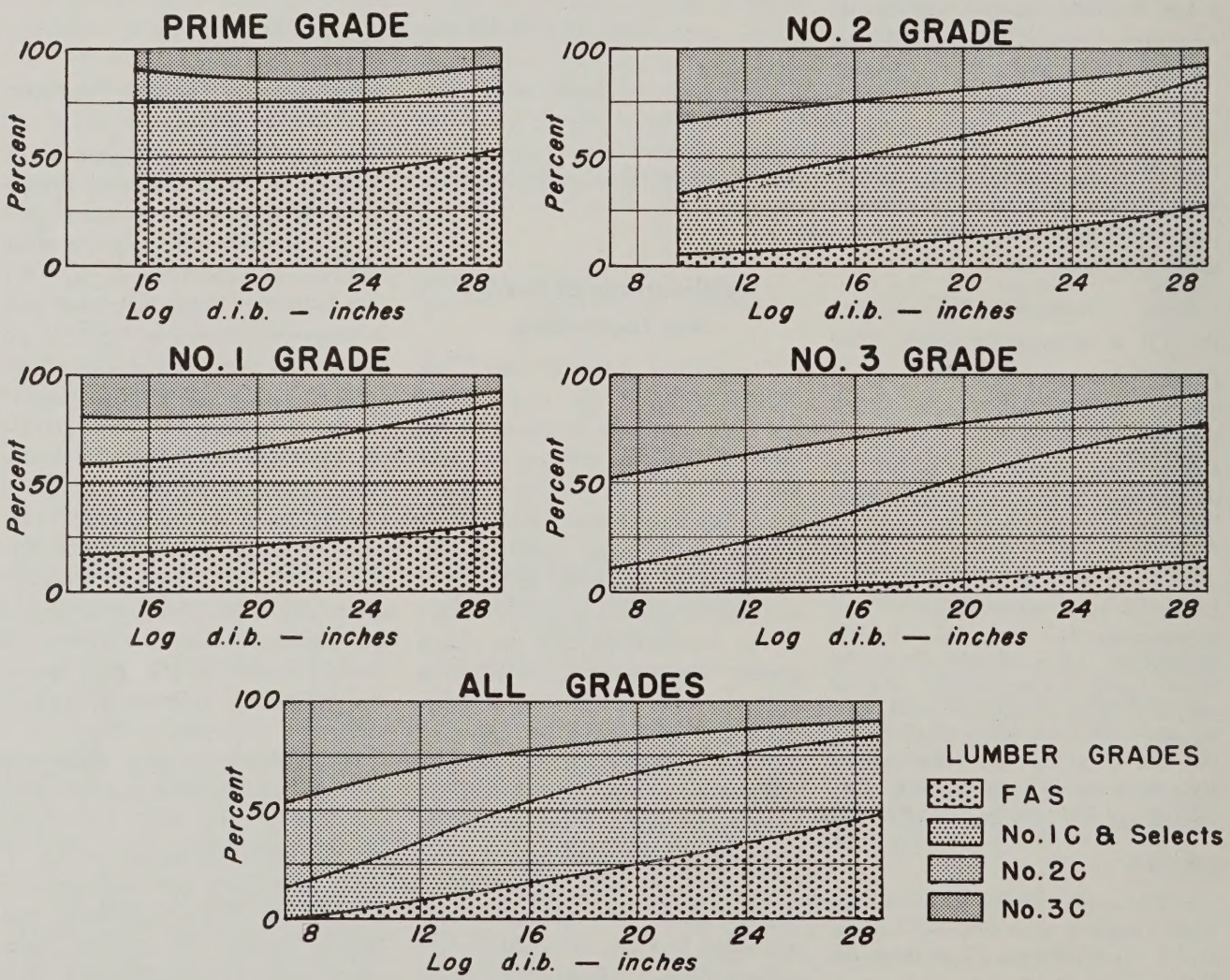

Figure 1. Hardwood lumber grade yields by log grade and log diameter.

grade yields. Figure 1 illustrates this fact. Close observation leads one to the conclusion that, for example, 20-inch, Grade No. 1 logs may be expected to saw out lumber of a better average quality than Grade 3 logs of the same size. Yet how much better? In larger-sized graphs it might be seen that a 20-inch, No. 3 log could be expected to yield about 54 percent No. 1C and better lumber, whereas the same-sized log would probably produce about 65 percent of these grades of lumber if it were a Grade 1 log. This is more specific information, but could be misleading because it tells nothing of the segregation of the "better grades" and the "lower grades" into their respective components. Indeed a recitation of the individual percentages is the only safe way in which to describe the relative qualities; such a recitation prevents specific comparisons because of the necessity of several different citations of grade yields. The only means of making precise comparisons among logs by using percentage grade yields is to convert the yields to a dollar value by multiplying each by its appropriate price.

Figure 2 shows the QI trends that match the five graphs of Figure 1. Each of the five curves in Figure 2 is a substitute for one of the subdivided percentage charts in the preceding figure. Here it may be seen that a 20-inch, Grade 3 log has a QI of 80 while that for a No. 1 log of the same size is about 93. This clearly demonstrates the superiority of the QI over grade yields for making quantitative comparisons of log quality; the value of the lumber in the No. 1 grade log is immediately calculable as being $100\left[\frac{93}{80}-1\right]=16.25$ percent greater than that in the poorer log.

Some general comments concerning Figures 1 and 2 are in order:

1—All grades included, the percentage yield of No. 1C and better lumber increases directly with log diameter.

2—The grade yield and QI are influenced less by log diameter in Prime logs than any other grade; yields from No. 3 grade logs are influenced most markedly by log size.

3—The yield of No. 1C and better lumber from large (24-inch, plus)

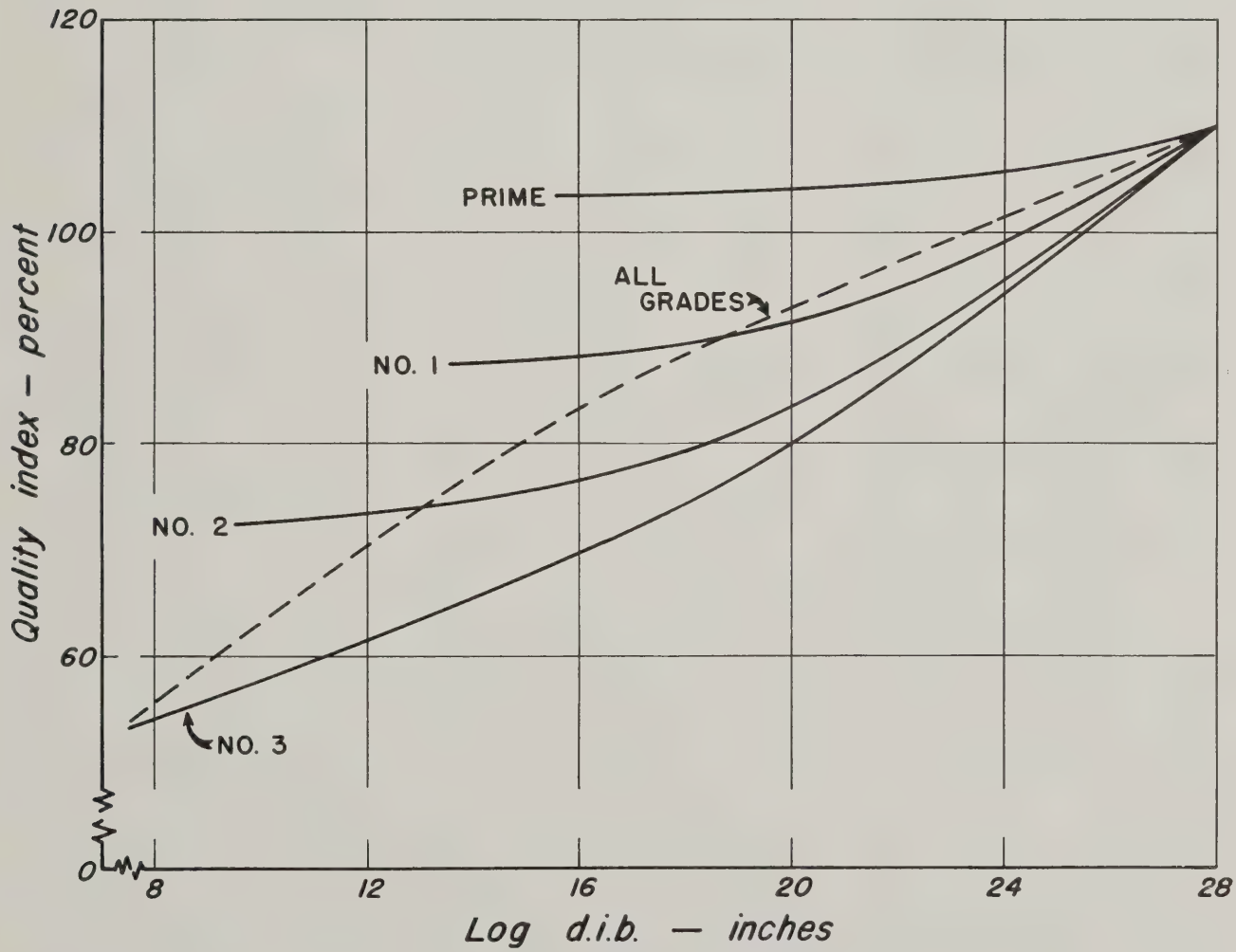

Figure 2. Regression of log QI on log diameter according to Purdue Log Grade.

logs is relatively independent of log grade. QI's for large logs are quite similar, also, regardless of log grade.

4—Regressions of QI on log diameter for the separate grades of log are all concave upward; the regression for "all grades combined" is convex upward.

In Appendix D are given the tabular equivalents of Figures 1 and 2. Table D-1 shows percentage grade recoveries and Table D-2 shows the corresponding QI values for various log diameters and log grades, with species pooled. Although different species do have characteristically different average grade yields and QI's, variance within species is great and reliability of means is low. Thus in most practical applications of grade recovery or QI data, species may be pooled for quality prediction. This means that Tables D-1 and D-2 include the quality information of the highest utility.

Sometimes there is need for "single species" grade recovery figures, as would be the case if an appraisal were to be made of just the yellow poplar trees in a given woods. Here, the use of specific yields or QI's would certainly provide more precise estimates than data compiled by pooling several species. Tables D-3 and D-4 in the Appendix show percentage grade yields and QI's for nine species or species groups by log diameters. Log grades are pooled. Table D-5 shows grade recovery data by species and log grade, but independent of log diameter. Its counterpart, Table D-6, includes mean QI's curved across log grades by species.

These data for the principal species seem to invite generalization as follows:

1—Viewed separately, the grade recoveries by log diameter for individual species are not appreciably different from the yields for all species taken together.

2—Logs of ash, basswood and poplar that are 18 inches or more in diameter yield scarcely any No. 3C lumber.

3—There is no one size of log that yields about equal volumes of the various lumber grades, in any species.

4—The FAS yields of beech and poplar[7] are lower than those of the other species in all sizes over 16 inches.

5—Of all species, white elm shows the greatest increase in yield of low grade lumber as log grade declines.

6—No. 1 grade logs of ash, basswood, red oaks and white oaks yield better quality lumber, on the average, than Prime logs of beech, hickory or poplar.

7—White oak logs of any grade seem to have a QI consistently higher by six index points than red or black oak logs of the same grade.

8—Poplar and hickory show the least amount of variation in lumber grade yields among the four log grades.

9—Ash and basswood, beech and cherry, and elm and soft maple, have, respectively, very similar QI's for any given grade of log.

These generalities about species, sizes and grades are to be qualified. The "species by log diameter" tables do not represent comparable grades of logs and likewise the "species by log grade" data do not necessarily derive from the same ranges or frequencies of log diameters.

The most detailed sort of quality information representative of "average logs" and not individuals is that ordered by log diameters, log grades and species. Separate tables showing yields of each grade of lumber from logs of different diameters are required for each grade of log for each species, if true percentage grade yields are to be indicated. For the nine principal species and the four log grades included herein, a total of 36 tables would be required to show such detailed grade recovery data. The equivalent QI values, however, are all shown in Table D-7.

The QI's in Table D-7 are generally of low reliability, that is, variance about the regressions of QI on log diameter was very high when the logs were segregated by log grade within species. This condition is due to the inherent inconsistency in lumber grade yields as well as to the small number of logs of certain species, grades and sizes. For sugar maple, only means for the four log grades are shown while for hickory a single, mean QI is given for Prime and No. 1 logs combined and another average value for all No. 2 and No. 3 logs. Clear definitions of trend were lacking for these species.

Aside from the fact that the QI's in Table D-7 for the most part increase with increases in log diameter and with improvement in log grade no generalization can be made. While it is true that some species exhibit QI's quite different from those characteristic of other species, this table illustrates that log grade and log size are much more important determinants of QI than is species.

Tree Grades and the Corresponding Tree QI's

A principal reason for the grading or the quality classification of any commodity is to appraise its relative worth. The determination of relative worth of trees may be done for the purpose of identifying those that would benefit from cultural work or it may be done to realize a price commensurate with their worth when the trees are marketed. In southern pine timber the grading of trees is often a matter of expressing the optimum use for the tree, as veneer, sawtimber, poles, piling, pulpwood, or other product, whereas in hard-

[7] The heartwood requirements in the FAS grade for yellow poplar make the yield of this grade relatively low from second-growth timber; the yield of saps and selects in this species is disproportionately high for the same reason.

woods, grading is typically a matter of discernment of sawlog quality. Thus the grades assigned to hardwood trees should reflect the potential yield of those trees in terms of lumber or other sawed products.

Because the application of log grades to standing timber has been hampered by complex grading rules and because the majority of the volume and value of a tree is to be found there, only the butt log is used to estimate tree quality in some tree grading systems. (Campbell, 1951 and 1955; Cummings and Zarger, 1953.) This practice is relatively simple, but contributes to inexactnesses because of the many possible combinations of upper log grades. There is no standard diminution of log quality above the butt log. Other systems have used the grade of both the butt and second logs (Martinelli, 1948) or even the grades of all of the logs (Guttenberg and Putnam, 1951; Burkle and Guttenberg, 1952; and Guttenberg and Reynolds, 1953) as an index of tree quality in an endeavor to refine the forecast of lumber quality or value. Ideally all logs in a tree should be considered when the tree is graded. However, to do this in a practical manner one must use a simple set of grading rules, or make a simple application of a complex set.

Tree grade is here defined as the unweighted arithmetic average of the Purdue log grade numbers, the Prime grade being designated as zero. A four-log tree with a Prime butt log, a grade No. 1 second log, a No. 2 third log and a No. 3 top log would be called a grade 1½ tree. $(0+1+2+3=6; 6\div 4=1\frac{1}{2})$. This grade designation does not imply that the quality of the lumber in such a tree is mid-way between that of grade No. 1 and No. 2 logs; due to taper and the fact that the upper logs are generally of the lower grades, the lumber in the tree will be of higher quality than the average of equal volumes of lumber from grade 1 and 2 logs.

Even though the log grade numbers are not weighted by log volume to find the tree grade, tree QI's corresponding to these tree grades must be computed by weighting the log QI's by the volumes of the various logs.

The determination of tree QI's by computation from the QI's of the individual logs is not feasible if many trees are involved. Rather, to be useful for extensive application, tree QI's must be precalculated. Since log diameter and log grade in combination define log QI fairly well and since log QI's weighted by log volumes produce a tree QI, the latter is ordinarily well correlated with tree d.b.h. and tree grade. The development of such a correlation is described below.

Beginning with hypothetical trees and assuming realistic amounts of taper[8], tree QI's were computed for

[8] For Indiana hardwoods butt log taper in merchantable trees averages between 3 inches and 8 inches per 12 feet depending upon tree size, species and site quality. (Herrick, 1949.) Top logs may taper from 2 inches to 5 inches per 12 feet depending upon tree form, and logs from the mid-bole usually average 1 inch of taper per 8 feet.

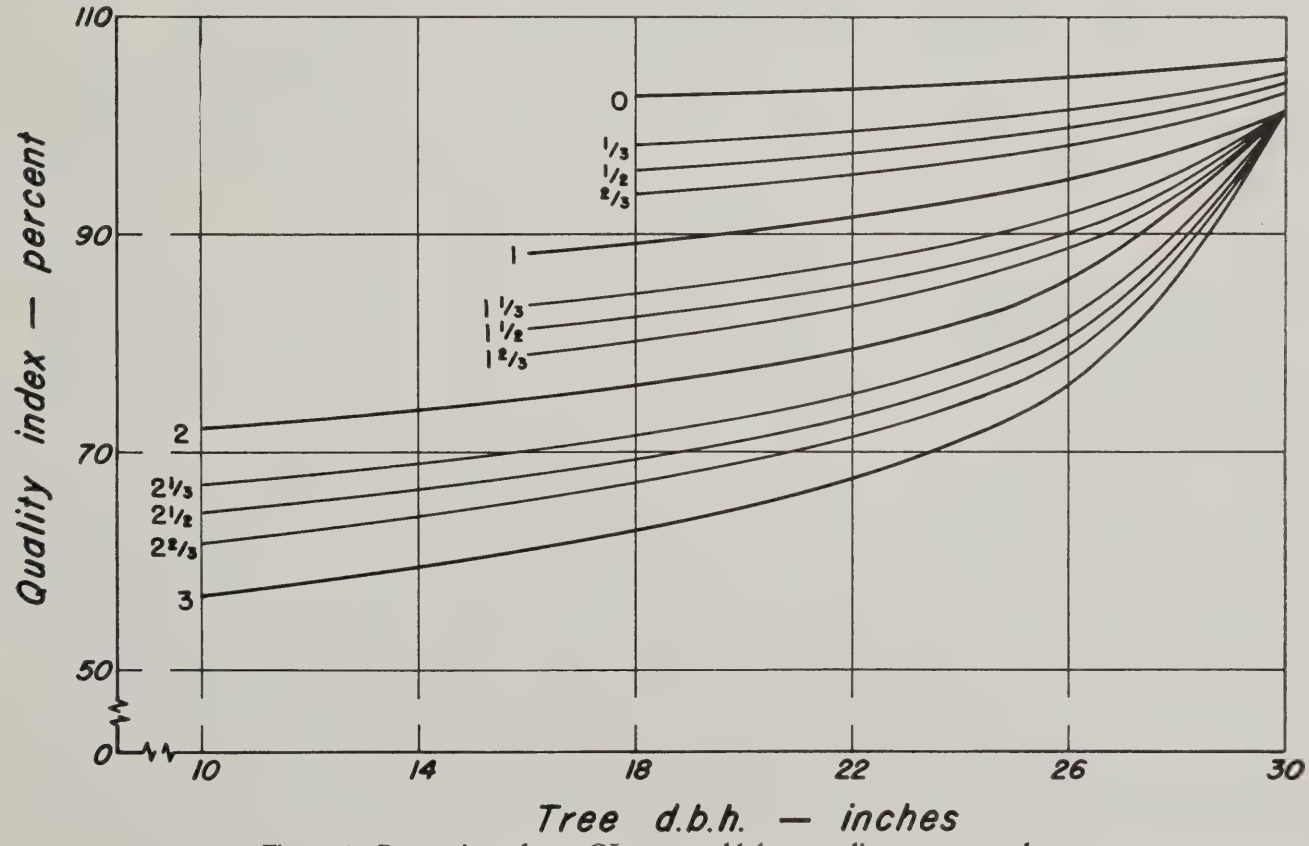

Figure 3. Regression of tree QI on tree d.b.h. according to tree grade.

12-, 16-, 20- and 24-inch d.b.h. trees of various log-grade compositions. This was accomplished by weighting the QI's of the individual logs in the tree by their volumes and computing the mean QI for the tree. (See Appendix, Table E-1.) Freehand regressions of tree QI on tree grade, one for each d.b.h. class, were plotted and then re-graphed: QI over d.b.h. ordered by tree grade to systematize the relationships. (See Figure 3.) Table E-2 showing tree QI's for various tree diameters and tree grades was read from Figure 3. Practical use of these tree QI's is illustrated in Part III.

For six hypothetical 18-inch grade 2 trees of different log compositions the mean tree QI figured 75.39 percent ± 0.47 percent and similarly for five differently-constituted, 22-inch grade 1 trees the mean QI was 92.10 percent ± 0.56. Thus it may be seen that the mean QI for trees of the same d.b.h. and tree grade is quite stable, even though the trees are constituted of logs of different grades and arrangements. Campbell (1951) found that estimated tree QI's showed only small mean differences from the actual QI's in a practical test in Appalachian hardwoods. The utility of the "tree as a whole" QI is, therefore, substantiated.

Stumpage Value in Contrast to Lumber Value; the Conversion Surplus

The quality index is an indirect expression of the value of the lumber in a tree or log, a value not "in the round," but as squared lumber. Foresters and timbermen usually desire to have an expression of value as stumpage or as logs, in the woods or at the mill "pond." The linkage between stumpage value and lumber value is cost and profit, to wit:

Stumpage value = Lumber value— (costs of conversion + margin for profit and risk).

Because profit margins are often indeterminate and the assignment of risk is open to much question, forest economists have modified this formula to include profit and risk with stumpage in a "conversion surplus."[9]

Conversion surplus = Product value — direct costs of conversion. The conversion surplus may be used for identification of the marginal tree as well as for the determination of the values of standing trees relative to one another. Yet the apportionment of the conversion surplus between stumpage value on the one hand and fixed costs and margin allowances on the other is a problem that defies generalization. One bidder for a block of timber in which he had but slight interest might figure stumpage as only 30 percent of the conversion surplus, whereas another, more interested bidder might use 70 percent of the surplus, as his bid price, satisfying himself with a smaller amount to cover fixed and margin charges. Hence the conversion surplus is but a guide to stumpage value.

To convert tree QI's into conversion surpluses in percent, a standard trend showing the relative cost per volume unit of converting trees into lumber was needed. In the course of another study several differential trends (by tree size) of costs of converting hardwood timber into lumber were examined (Herrick, 1945). Although each of these trends was unique, one reported by Shames (James), (1946) seemed to be fairly representative of (relative) hardwood logging and milling costs.[10] As in Table E-3, Shames' dollar cost figures were converted to percentages, with the trend (Figure 4) being "pegged" at 60 percent at the 16-inch diameter. This merely provided a means whereby the relative costs could be used in conjunction with the QI's to obtain relative conversion surpluses.

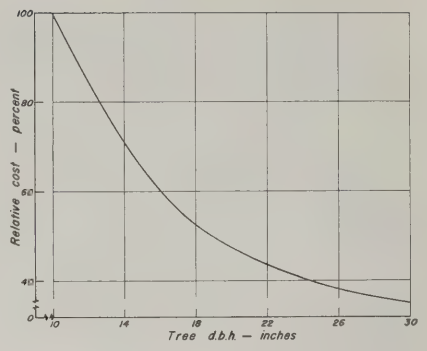

Figure 4. Differential logging and milling cost trend.

When the relative costs were deducted, for each diameter class, from the tree QI's in Table E-2, there remained a conversion surplus in percent. Since the QI's were in percent (of the No. 1 Common lumber price) it may be considered that the conversion surplus figures are in percent of the same base. In effect, then, the cost trend allowed 60 percent of the selling price of No. 1 Common lumber as the cost of conversion for 16-inch trees. If rough, green No. 1 Common lumber were selling for $80.00 per M bd. ft., the allowance for all direct costs would be $48.00 per M for 16-inch trees and $42.40 per M (0.530 x $80) for 18-inch trees.

The conversion surplus figures are in Table E-4 and in graphic form in Figure 5. They reflect the influence of tree size and tree grade upon the value of the lumber yield and the influence of tree size upon conversion costs per M bd. ft. They are limited in use, however, because they intimate that conversion costs are directly related to species selling prices; the higher the dollar price, the higher the absolute allowance for cost. This fallacy means that the relative conversion surplus figures must be used only for making comparisons among tree sizes and/or grades or else the user must expect only approximate results if the surpluses are converted from percentages to dollars.

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[9] See footnote 5, Page 5.

[10] Burkle and Guttenberg (1952) used this same source and, in general, made the same application in determining conversion surplus.

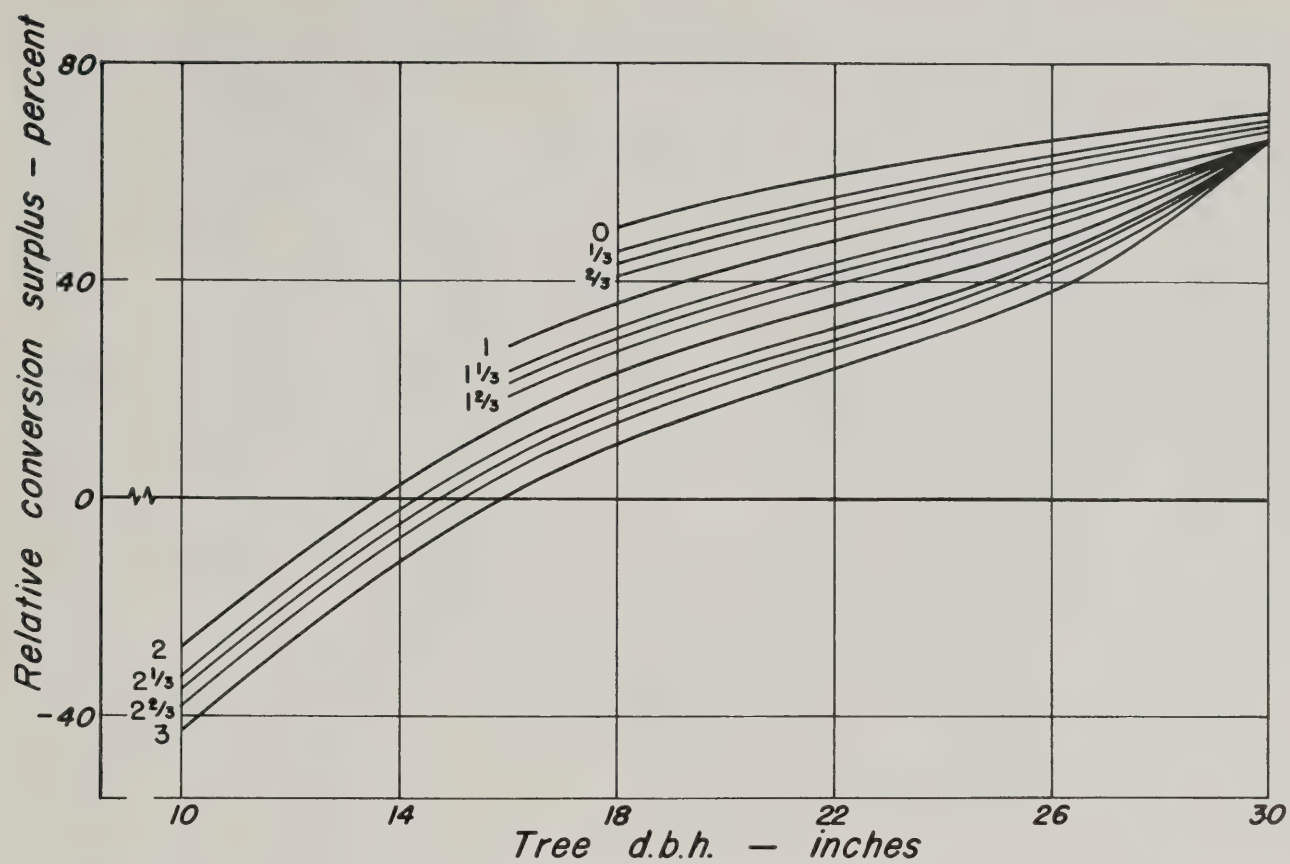

Figure 5. Regression of relative conversion surplus on tree d.b.h. according to tree grade.

III. Application of the QI Concept in Stumpage Appraisal

Timber Appraisal Has Become Analytical

Appraisal of standing timber once involved merely the determination of net timber volume and the application of a flat price per unit. In coniferous timber this practice has persisted somewhat longer than in hardwoods, but it is generally true that the quality or grade of the trees now receives more attention than it ever did in the past. Less plentiful supplies of stumpage, increased costs of production and higher market prices for premium timber products have all contributed to this emphasis on quality. Though economic conditions have been primarily responsible, use of the quality index has permitted far more intensive treatment of timber quality than has heretofore been feasible. In any major hardwood-producing area, it is highly probable that timber estimation by grade will completely supplant the old-style cruises by volume only.

There are two basic methods for estimating the merchantable volumes of standing trees: 1) using the tree dimensions and applying a volume table, and 2) using the dimensions of the component logs and applying a log rule. With the former method, quality can best be evaluated "by the tree" through use of a tree grade; the latter method requires the grading of the individual logs. The QI "translates" the tree or log grade information into terms of the lumber value yields, thus allowing an objective assay of the estimated outturn of the trees or logs.

Appraisal of stumpage may be a relatively crude process such as that described above, wherein a set price per volume unit is applied to the net volume estimated. Or, it may be a highly refined, analytical process whereby detailed costs of logging and milling, differentiated among the several diameters are added to an allowance for profit and risk and the whole subtracted from the anticipated product value.

Whatever the process involved, the basic principle is to reduce the anticipated selling price of the product or products by all costs of conversion and an allowance for profit and risk. (See Formula, Page 10.) Herein, no attempt is made to apportion the conversion surplus among stumpage, fixed costs and margin for profit and risk.

Basic data for illustrating the appraisal of standing timber are given in Table 4. These 20 trees were selected arbitrarily from an appraisal of an old-growth woods made in 1953 in Tippecanoe County, Indiana. Reference lumber grade (No. 1C) prices have been assumed from recent air-

dry, 4/4 quotations. Two methods are used for finding the lumber tally corresponding to the 5,252 board feet of Doyle log scale: 1) by reference to a table of mill tally volumes, and, 2) by adding the estimated overrun in board feet to the Doyle volumes. Likewise, three separate techniques are employed in determining the conversion surplus for these 20 trees: 1) using QI's for individual logs and deducting a cost allowance, 2) using tree QI's and deducting a cost allowance, and, 3) using conversion surpluses for individual trees. These techniques are but three of more than a dozen possibilities, considering the use of grade yield percentages in addition to QI's and the several options for estimating QI's and grade yields. In Table 5 the Doyle log scale and the estimated band mill tally have been entered according to log grades; the mill tally figures were taken from Table B-2 in the Appendix.

TABLE 4. Basic Data for Sample Appraisals.

Species	d. b. h.	Log Data[1] 1st	2nd	3rd
Red O.	24	18.16.P	16.16.1	14.12.1
Wh. O.	23	17.16.1	15.12.1	
Wh. elm	18	15.12.1	12.12.2	
Wh. ash	16	10.16.2		
Red O.	29	22.16.P	19.16.P	17.10.2
Bassw'd	23	18.10.P	15.14.1	14.12.2
Red O.	33	26.14.P	20.12.P	
Wh. elm	20	16.12.P	13.12.2	
Wh. elm	26	20.16.P		
Red O.	24	17.12.P	14.12.3	
Bassw'd	20	15.12.1	12.16.2	
Bassw'd	17	12.16.2		
Wh. elm	20	17.12.P		
Wh. elm	18	13.18.2		
Wh. O.	30	22.12.P	18.16.2	
Wh. O.	26	20.12.P	18.12.P	14.12.2
Red O.	28	20.16.P	17.12.2	
Wh. elm	22	16.12.1	14.12.2	
Red O.	28	16.12.P	14.16.1	
Red O.	19	15.12.1	12.12.2	

[1] In sequence: scaling diameter in inches, scaling length in feet and the Purdue log grade (from estimates made in field).

TABLE 5. Preliminary Analysis for Sample Appraisals.[1]

Species	d.b.h.	Doyle Log Scale by Grades[2] P	1	2	3	Total	Lumber Tally by Log Grades[3] P	1	2	3	Total
Red O.	24	196	144 } 75 }			415	233	177 } 102 }			512
Wh. O.	23		169 } 91 }			260		205 } 118 }			323
Wh. elm	18		91	48		139		118	82		200
Wh. ash	16			36		36			81		81
Red O.	29	324 } 225 }		106		655	360 } 264 }		132		756
Bassw'd	23	122	106	75		303	147	137	102		386
Red O.	33	423 } 192 }				615	452 } 228 }				680
Wh. elm	20	108		61		169	134		92		226
Wh. elm	26	256				256	296				296
Red O.	24	127			75	202	155			102	257
Bassw'd	20		91	64		155		118	105		223
Bassw'd	17			64		64			105		105
Wh. elm	20	127				127	155				155
Wh. elm	18			90		90			68		68
Wh. O.	30	243		196		439	285		233		518
Wh. O	26	192 } 147 }		75		414	228 } 176 }		102		506
Red O.	28	256		127		383	296		155		451
Wh. elm	22		108	75		183		134	102		236
Red O.	20	108	100			208	134	134			268
Red O.	19		91	48		139		118	82		200
						5,252	3,543	1,361	1,441	102	6,447

[1] More than one number in any log grade category for the same tree indicates more than one log of a given grade in that tree.
[2] Entered in office from Table B-1.
[3] Entered in office from Table B-2.

Appraisal Using Individual Logs

The first appraisal is done by species and log grade. Table 6 presents a summary of mill tally volumes for the five species, the four log grades and appropriate totals. QI's that ignore both species and log size are multiplied by the No. 1C price for each species; these cross-products (the mill-run lumber price, all grades included) are then applied to the volume in each species-log grade category. For example, the QI for No. 2 logs is 79 percent. This figure is multiplied by the selling price of the No. 1C grade of lumber, $100 per M in the case of white ash, thus: 0.79 x $100 = $79 per M, the estimated mill-run price of the lumber contained in Grade No. 2, white ash logs. When the $79 is applied to the 81 board feet of lumber in this category ($79 per M x 0.081 M) the resultant $6.40 represents the actual value of this amount and kind of lumber. Other value figures in Table 6 were obtained in this same manner. The QI's used in this illustration are to be found in Table D-2, at the bottom.

Total product (lumber) value of these 20 trees amounts to $706.43 and this must be reduced by the estimated total production costs to find the conversion surplus. The latter process is shown below Table 6. From Figure 4, Page 10, the relative production cost corresponding to the average d.b.h. of these 20 trees (22.8 inches) was found to be 42.2 percent (of the No. 1C lumber price). The weighted (by volume) selling price of No. 1C lumber of these five species computed to be $114.52, thus the production cost figured $48.33 per M ($114.52 per M x 0.422). At this rate, the estimated total cost of producing the 6.447 M board feet of lumber was $311.58. When this total cost was deducted from the total lumber value, the conversion surplus amounted to $394.85.

TABLE 6. Appraisal Using Individual Logs.

Species	No. of trees	No. 1C Price	Log Grades: P	1	2	3	All
			Quality Index in Percent: 105	90	79	68	
		($)	Board feet, mill tally and dollars[1]				
Wh. Ash	1				31		81
		100			6.40		6.40
Bassw'd	3		147	255	312		714
		120	18.52	27.54	29.58		75.64
Wh. elm	6		585	252	344		1,181
		80	49.75	18.37	21.74		89.86
Red Oak	7		2,122	531	369	102	3,124
		120	267.37	57.35	34.98	8.32	368.02
Wh. Oak	3		689	323	335		1,347
		130	94.05	37.79	34.67		166.51
All	20		3,543	1,361	1,441	102	6,447
		...	429.69	141.05	127.37	8.32	706.43

[1] Mill tally volumes summarized from Table 5.

Dollars of lumber value = QI x #1C price x Volume in M. bd. ft.

Derivation of total conversion surplus (see explanation this page):

Total lumber value	$706.43
Less Costs:	
@ mean d.b.h. of 22.8"	42.2%
weighted No. 1C price	$114.52
average cost, per M	$48.33
$48.33 per M x 6.447 M	311.58
Conversion surplus, 20 trees	$394.85

Appraisal by the Tree Using QI's

In the second illustration of stumpage appraisal, the individual tree is the basis. Species, d.b.h. figures and Doyle volumes per tree have been listed in Table 7 from Table 5. Overrun per tree was determined from a formula. An earlier study by Herrick (1946a) showed that band mill overrun in board feet from the Doyle scale could be computed for logs averaging 12 feet in length from the following regression equation:

$$\text{Overrun per log} = 40 - d/2,$$

wherein "d" is the scaling diameter of the log. This equation was combined with the Purdue rule-of-thumb (Herrick, 1939 rev. 1948) which says that "the scaling diameter of the average (12-foot) log in a hardwood tree equals three-fourths of the d.b.h. Hence, if "D" equals the tree d.b.h. and "N" equals the number of logs per tree—

$$\text{Overrun per tree} = N\,(40 - d/2), \text{ but } d = 3/4\ D, \text{ so}$$
$$= N\,(40 - 3/8D)$$

For a 24-inch, 3-log tree, the overrun figures:

$$3\,[\,40 - (3/8)(24)\,] = 3\,(40 - 9) = 93 \text{ board feet.}$$

Each of the tree volumes in Doyle scale was converted to mill tally by adding the appropriate overrun computed in the above manner. Total mill tally estimated in this way equaled 6,464 board feet as compared with 6,447 feet determined in Table 5.

Tree grades shown in Table 7 are merely unweighted averages of the grades of logs in the several trees. The first tree, for example, shows a grade of 2/3 because it contains a Prime (counted zero) and two No. 1

TABLE 7. Appraisal by the Tree Using Quality Indices.

Species	d.b.h. (in.)	Doyle scale (b.f.)	Over-run (b.f.)	Mill tally (b.f.)	Tree grade —	Tree Q.I.[1] (%)	Conv. surplus[2] (%)	No. 1C price ($)	Conversion surplus ($)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Red O.	24	415	93	508	⅔	96	54	120	32.92
Wh. O.	23	260	62	322	1	92	50	130	20.93
Wh. elm	18	139	66	205	1½	82	40	80	6.56
Wh. ash	16	36	34	70	2	75	33	100	2.31
Red. O.	29	655	87	742	⅔	101	59	120	52.53
Bassw'd	23	303	93	396	1	92	50	120	23.76
Red. O.	33	615	56	671	0	106	64	120	51.53
Wh. elm	20	169	64	233	1	90	48	80	8.95
Wh. elm	26	256	30	286	0	104	62	80	14.19
Red. O.	24	202	62	264	1½	87	45	120	14.26
Bassw'd	20	155	64	219	1½	84	42	120	11.04
Bassw'd	17	64	34	98	2	75	33	120	3.88
Wh. elm	20	127	32	159	0	103	61	80	7.76
Wh. elm	18	90	33	123	2	76	34	80	3.35
Wh. O.	30	439	58	497	1	101	59	130	38.12
Wh. O.	26	414	90	504	⅔	98	56	130	36.69
Red. O.	28	383	60	443	1	98	56	120	29.77
Wh. elm	22	183	64	247	1½	85	43	80	8.50
Red. O.	20	208	64	272	½	96	54	120	17.63
Red. O.	19	139	66	205	1½	83	41	120	10.09
Total	456	5,252	1212	6,464					394.77
Mean	22.8								

[1] Entered from Table E-2

[2] QI reduced by 42. At mean d.b.h. (22.8 inches) the relative cost = 42.2%

Summary by Species

	No. of Logs	Volume bd. ft.
Wh. ash	1	70
Bassw'd	3	713
Wh. elm	6	1,253
Red O.	7	3,105
Wh. O.	3	1,323
	20	6,464

grade logs; the sum of the grades, $(0 + 1 + 1 = 2)$ is divided by the number of logs in the tree (3).

The quality index figures from Table E-2 were entered in Table 7 according to the d.b.h. and grade of each tree and these QI's were then reduced by 42 percent (rounded from 42.2), the average relative production cost for trees averaging 22.8 inches in d.b.h., as determined before. The remainder represented, for each tree, the conversion surplus per unit of volume, in percent of the No. 1C selling price. By cross-multiplying the mill tally volume per tree (in M's), the relative conversion surplus and the lumber selling price of the No. 1C grade of the particular species, the conversion surplus in dollars was obtained for each tree. For the first tree, a 24-inch, grade 2/3 red oak, the QI (Table E-2) is 96 percent. This, less the cost allowance of 42 percent gives a conversion surplus of 54 percent. Then, in dollars, the surplus for the tree figures: 0.508 M x 0.54 x $120 = $32.92. The sum of the surplus figures for the 20 trees is almost identical with the total conversion surplus calculated from the individual log data. This attests to the legitimacy of using QI's for the entire tree.

Appraisal by the Tree Using Conversion Surpluses

A modification of this "by-the-tree" type of appraisal gives recognition to the fact that conversion costs vary according to tree size. Whereas the conversion surplus per tree in Table 7 was equal to the QI reduced by a standard percentage for a cost allowance, the surplus figures (percentages) in Table 8 were entered directly from Table E-4. The estimated total conversion surplus for the 20 trees amounted, in this case, to $406.75 or about $12 more than that figured by the other two methods. The excess here may be explained by the lower differential costs applied for the large trees well above the mean d.b.h. In the first two methods 42 percent was the cost allowance for all sizes of trees, whereas in Table 8, the allowance for a 30-inch tree was only about 35 percent (See Table E-3). Although it is true that higher costs are deducted for the smaller-than-average trees, the resulting surpluses do not compensate the total because the tree volumes are so much smaller.

Stumpage Appraisal Generally

When an appraisal is made by individual logs a QI for each log may be utilized if desired, although increased precision seldom warrants this refinement. In the illustration here given, log diameter and length are estimated for volume, log grade for QI's and species is recorded for pricing. Pooling of all volumes in a species-log grade category greatly simplified the computations. Appraisals made "by the tree" do not require an estimate of the diameters and lengths of the logs in each tree if a suitable volume table is available, but the grades of the logs are necessary in determining the tree grade as defined herein. The d.b.h. and usable length give the volume estimate, the d.b.h. and tree grade control the QI (Table E-2) or relative conversion surplus (Table E-4) and, again, the species dictates the selling price of the No. 1C grade. Direct use of the relative conversion surplus in percent allows the ready calculation of the corresponding surplus in dollars for each tree, although such use of the conversion surplus may be open to question. (See Page 10.)

TABLE 8. Appraisal by the Tree Using Conversion Surpluses.

Species	d.b.h. (in.)	Tree Grade —	Mill Tally (b.f.)	No. 1C Price ($)	Convers. Surplus (%)	Convers. Surplus ($)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Red. O.	24	⅔	508	120	55.8	34.02
Wh. O.	23	1	322	130	50.1	20.97
Wh. elm	18	1½	205	80	29.8	4.89
Wh. ash	16	2	70	100	14.8	1.04
Red. O.	29	⅔	742	120	65.9	58.68
Bassw'd	23	1	396	120	50.1	23.81
Red O.	33	0	671	120	71.1	57.25
Wh. elm	20	1	233	80	42.6	7.94
Wh. elm	26	0	286	80	66.4	15.19
Red O.	24	1½	264	120	46.6	14.76
Bassw'd	20	1½	219	120	36.3	9.54
Bassw'd	17	2	98	120	19.5	2.29
Wh. elm	20	0	159	80	55.5	7.06
Wh. elm	18	2	123	80	23.4	2.30
Wh. O.	30	1	497	130	66.1	42.71
Wh. O.	26	⅔	504	130	60.0	39.31
Red O.	28	1	443	120	61.2	32.53
Wh. elm	22	1½	247	80	41.8	8.26
Red O.	20	½	272	120	49.1	16.03
Red O.	19	1½	205	120	33.2	8.17
Total			6,464			406.75

IV. Development of An Economic Marking Guide

Timber Marking is More Than Economics

No objective timber-marking guide can ever substitute for judgment on the part of the marker. And no marking guide of a purely economic sort should ever be used to the exclusion of sound silvicultural principles. Timber marking is and will continue to be an art. However, when indecision about whether a tree should be marked cannot be resolved otherwise, then an objective system of evaluation is highly desirable. A logical application of the conversion surplus is in the development of such economic marking guides.

Since surplus figures may be directly compared between two different tree diameters, the appreciation in quality—that is, in the relative unit conversion surplus—is readily attainable. Thus the conversion surplus for a Grade No. 1, 23-inch tree that grows to a 24-inch d.b.h. increases from 50.1 to 52.3 percent (See Table E-4). Suppose the tree were of form class 80 and contained 32 feet of merchantable length. The gross International ¼-inch volume would increase from 428 to 469 board feet (Mesavage and Girard, 1946). Now, assuming that the No. 1 Common lumber selling price for the species is $80 per M bd. ft., the increment in dollar value accompanying the one-inch increase in tree size may be computed as:

$$\$80\ [\ (0.523 \times .469) - (0.501 \times .428)\ ] = \$2.47$$

If this dollar increment were associated with a five year time period (five rings per radial one-half inch) the annual increment would obviously be:

$$\$2.47 \div 5 = \$0.494$$

At the same lumber selling price, a 13-inch, Grade No. 2 tree that increases from 71 to 83 board feet in growing one inch in d.b.h., would yield a total dollar increment of:

$$\$80\ [\ (0.029 \times 0.083) - (-0.041 \times 0.071)\ ] = \$0.425$$

Even if this tree were to increase from 13 to 14 inches in d.b.h. in a single year, its annual dollar increment would still be lower than that of the larger tree. On the other hand if the smaller tree were of a species for which the selling price of No. 1C lumber were $100 per M bd. ft., at one inch of growth per year it would earn more annually (53 cents) than the larger tree.

Guide Numbers are Increments in Conversion Surplus

The marking guide numbers in Table E-5 have been developed using volumes from a "local" volume table (Herrick, 1946b). The latter (Table B-4, Appendix) is in International, ¼-inch, scale and is suitable for "local" Indiana merchantable lengths. Guide numbers are merely the increases in conversion surplus per inch of d.b.h. growth. If the selling price of No. 1C lumber is $100 per M bd. ft. then these numbers are increments in the surplus in cents. For a Grade No. 1 tree that grows from 18 inches to 19 inches, the volume increases from 281 board feet to 323 board feet while the conversion surplus changes from 36.4 percent to 39.7 percent. Thus the guide number computes as:

$$(0.397 \times 0.323) - (0.364 \times 0.281) = 0.025947$$

or $0.025947 \times \$100 \times 100$ cents per dollar = 259.47 cents.

All values in Table E-5 were calculated in this same manner.

Since this guide number is associated with one inch of increase in d.b.h. it must be related to the growth rate to be converted to an annual basis. This is accomplished, as before, by dividing by the number of rings in the last radial one-half inch.

Likewise the guide numbers should be adjusted for species differences by multiplying by factors such as those at the bottom of Table E-5. These factors should approximate the relationships existing among the No. 1C selling prices of the various species in a free market and under current typical conditions of demand. Although the number resulting from the use of these or similar factors may not be a close approximation of the monetary value of the annual increase in conversion surplus, it will be a good estimate of the increase relative to the value increments of other trees.

Growth in diameter typically decelerates as trees become larger. Yet the value of one inch of growth in d.b.h. increases with an increase in tree size; the growth represents more volume and higher quality wood on the larger stem. Tree grade further confounds the issue. Reference to Table E-5 will verify the facts that leaving a tree for one additional inch of diameter growth:

—gives the greatest value increment on the better grade trees, up to 24 inches d.b.h.

—gives practically the same value increment, regardless of tree grade at a 25 inch d.b.h.

—gives the greatest value increment on the lower-grade trees, if over 25 inches in d.b.h.

The interaction of d.b.h., tree grade and growth rate can best be illustrated by some examples.

Growth Rate and Species Value are Applied to the Guide Numbers

Consider a situation in which one of two red oaks is to be marked for cutting. Tree "A" is a 16-inch, Grade 2 tree with 6 rings in the last radial **inch.** Tree "B" is 22 inches in d.b.h., Grade 1½ and shows 10 rings per radial **inch.** Which tree will be the less productive in the next few years? Dividing the guide number[11] from Table E-5 by the number of years required to grow one inch of **diameter** gives the answer.

Tree "A" $\quad 170 \div 3 = 56.7$

Tree "B" $\quad \dfrac{364 + 322}{2} \div 5 = 68.6$

Though the difference is not great, the larger tree should be left and Tree "A" marked for cutting. The grade improvement of Tree "B" more than offsets its slower growth rate.

Suppose Tree "C," a 20-inch hard maple, Grade 1⅔ is in competition with Tree "D" a beech, Grade 1 and 18 inches in d.b.h. If the maple shows 11 rings in the last radial **inch** and the beech, 8 rings, which tree is the poorer producer of value? Again, dividing the guide number[12] by the number of rings in the last one-half inch of radius, but weighting the result by the different species value factors:

Tree "C" $\quad [(334)\ 1/3 + (278)\ 2/3] \div \dfrac{11}{2} \times 1.0 = 297 \div 5.5 = 54.0$

Tree "D" $\quad (259 \div 4)\ 0.8 = 51.8$

Of the two, the beech (Tree "D") would be marked for cutting. Even though "D" is a higher grade, faster growing tree, beech lumber is worth less than hard maple and the species factor causes the relative value increment of the latter to be higher than that of the beech tree. Here the difference is nearly inconsequential.

In either of the cases just used for illustration, the correct selection of one tree over another could not have been made easily, yet objectively, without the assistance of the table of marking guide numbers. Defect is so prevalent in nearly all existing stands of hardwoods in Indiana and the Central-West that the identification of trees for cutting is not a difficult problem. Thus it is seldom necessary to resort to a critical examination of them before trees are marked. Yet in the instances where subjective appraisal produces indecision or bias, the marking guide numbers are worthy of application.

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[11] Interpolation is necessary for tree "B."

[12] Interpolated for Tree "C."

Appendix A

Glossary of Selected Terms and Abbreviations

d.b.h.—diameter at breast height—4½ feet above average ground level outside of bark.

d.i.b.—diameter inside of bark at the small end of a log; the scaling diameter.

four-quarter or 4/4—nominal one-inch thickness, applied to lumber.

lumber grades—(see below).

FAS—firsts and seconds

Sel.—selects

No. 1C—number one common

No. 2C—number two common

No. 3C—number three common

[1] Society of American Foresters (1950).

M or M. bd. ft.—one thousand board feet.

plain sawed—lumber so sawed that the growth rings form an angle of less than 45 degrees with the surface of the piece.[1]

p.r.—price relative; the ratio of the dollar price of a given grade of lumber to the price of the No. 1C grade.

QI—quality index; a percentage related to the lumber value of a tree or log.

timber marking—selection and indication, usually by blaze or paint spot, of trees to be cut or retained in a cutting operation.[1]

Appendix B

Accessory Descriptions and Data

Brief description of hardwood lumber grades
Purdue log grades
Table B-1—Doyle Log Rule
Table B-2—Band Mill Tally
Table B-3—Circle Mill Tally
Table B-4—Composite volume table for Indiana hardwoods, International (¼-inch) scale.

A Brief Description of Hardwood Lumber Grades

The following excerpts from, "How Lumber Is Graded" (Betts and Helphenstine, 1920) will serve as a brief summary of hardwood lumber grades:

"The highest grade of hardwood lumber is termed 'Firsts' and the next grade 'Seconds.' Firsts and Seconds, or, as they are generally written, FAS are practically always combined in one grade. The third grade is termed 'Selects' followed by No. 1 Common, No. 2 Common, Sound Wormy, No. 3-A Common, and No. 3-B Common."

"The highest grade, Firsts, calls for pieces which will allow a 91⅔ percent of their surface measure to be cut into clear-face material; i. e., not more than 8⅓ percent of each piece can be wasted in making the required cuttings. In the grade of Seconds, 83⅓ percent of the surface measure of the pieces must yield clear-face cuttings.[1] Both Firsts and Seconds requires pieces not less than 6 inches wide and 8 feet long. In the grade Selects the minimum width is 4 inches and the minimum length, 6 feet. Both First and Seconds and the face side of Selects must in addition to cutting requirements also meet specified requirements as to the limitation of certain defects. The cutting requirements of Selects are 91⅔ percent clear face in pieces with 2 and 3 surface feet. In larger pieces, the cutting requirements are the same as for Seconds on the face side. The reverse side of the cuttings in Selects must be sound or the reverse side of the piece not below No. 1 Common. The next two grades, No. 1 Common and No. 2 Common, call for material not less than 3 inches wide and 4 feet long and require[2] 66⅔ percent and 50 percent clear-face cuttings, respectively. The minimum size of cuttings in these two grades is reduced from 4 inches by 5 feet or 3 inches by 7 feet in Firsts, Seconds, and Selects to 4 inches by 2 feet or 3 inches by 3 feet.

"In the grade of Sound Wormy the requirements are the same as in No. 1 Common except that worm holes and similar defects are allowed in the cuttings. The grade of 3-A Common admits pieces that will furnish 33⅓ percent clear face in cuttings not less than 3 inches wide and 2 feet long. This grade will also admit pieces which grade not below No. 2 Common on the good face and have the reverse face of the cutting sound. The lowest grade, No. 3-B Common, allows pieces that will cut 25 percent in sound material not less than 1½ inches wide and having at least 36 square inches surface measure."

[1] Boards 6 feet to 15 feet surface measure will admit of one additional cutting to yield 91⅔ percent clear face.

[2] Exceptions in No. 1 Common are pieces with 1 foot surface measure and 2 feet surface measure, which require 100 percent clear face and 75 percent clear face, respectively, and in No. 2 Common pieces with 1 foot surface measure, which require 66 percent clear face.

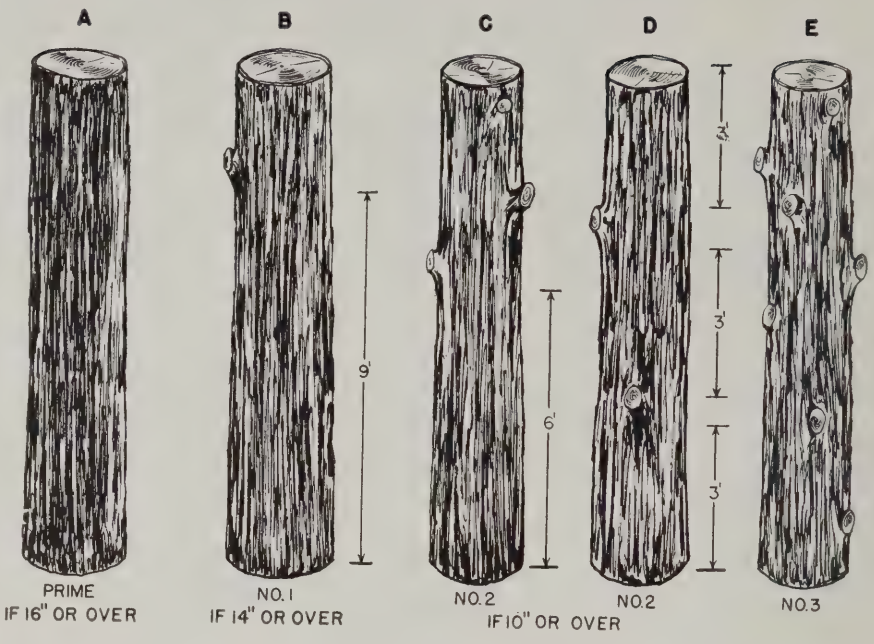
Purdue Hardwood Log Grades

Prime—Practically (90 percent) surface clear on three visible faces.[1] (A face is any one-quarter of the surface of a log.) Must be 16 inches or more in diameter inside bark at the small end.

No. 1—At least three-fourths (75 percent) of the log length on the three visible faces must be surface clear in one section. Must be at least 14 inches in diameter inside bark at the small end.

No. 2—At least one-half (50 percent) of the log length must be surface clear on the three visible faces in one section or in two sections, neither of which can be less than three feet long. Must be at least 10 inches in diameter inside bark at the small end.

No. 3—Will not meet No. 2 specifications.



[1] When one has occasion to see all sides of a log, as in timber cutting or log making, only the **three poorest faces** should be used in grading the log.

TABLE B-1. Doyle Log Rule.

Top diameter (inches)	Length in Feet				
	8	10	12	14	16
	Volume in Board Feet				
8	8	10	12	14	16
9	13	16	19	22	25
10	18	23	27	31	36
11	25	31	37	43	49
12	41	51	61	71	81
13	41	51	51	71	81
14	50	63	75	87	100
15	61	76	91	106	121
16	72	90	108	126	144
17	85	106	127	148	169
18	98	123	147	172	196
19	113	141	169	197	225
20	128	160	192	224	256
21	145	181	217	253	289
22	162	203	243	284	324
23	181	226	271	316	361
24	200	250	300	350	400
25	221	276	331	386	441
26	242	303	363	424	484
27	265	331	397	463	529
28	288	360	432	504	576
29	313	391	469	547	625
30	338	428	507	592	676
31	365	456	547	638	729
32	392	490	588	686	784
33	421	526	631	736	841
34	450	563	675	788	900
35	481	601	721	841	961
36	512	640	768	896	1024
37	545	681	817	953	1089
38	578	723	867	1012	1156
39	613	766	919	1072	1225
40	648	810	972	1134	1296

TABLE B-2. Mill Tally in Six Indiana Band Mills.

Log d.i.b. inches	Log length in feet				
	8	10	12	14	16
	Board feet				
8	10	27	43	54	59
10	29	47	63	73	81
12	48	68	82	94	105
14	67	90	102	120	134
16	85	118	134	155	177
18	104	147	176	203	233
20	122	182	228	260	296
22	141	228	285	326	360
24	160	281	341	388	426
26		334	397	452	487
28		338	454	514	550
No. of logs	34	136	264	124	79

TABLE B-3. Mill Tally in Seven Indiana Circular Mills.

Log d.i.b. inches	Log length in feet				
	8	10	12	14	16
	Board feet				
8	23	30	34	39	45
10	36	47	54	62	72
12	49	67	76	86	100
14	62	86	100	113	130
16	75	112	130	147	165
18	88	140	166	189	210
20	101	172	211	242	268
22		206	261	301	333
24		243	316	363	405
26			369	426	482
28			423	488	560
No. of logs	31	37	38	40	28

TABLE B-4. Merchantable Volume Table for Indiana Hardwoods[1] Board Feet—International (1/4-inch) Rule

Tree d.b.h. (inches)	Average tree	Merchantable height in 12-foot logs[3]					
		1	2	3	4	5	6
	Volume in board feet, International (1/4") scale						
10	29	20	32				
12	73	42	70	93			
14	135	68	116	153	180		
16	204	90	159	212	253	296	
18	281	112	202	275	335	396	
20	366	139	249	344	428	505	
22	468	178	306	431	538	636	744
24	574	218	368	522	655	770	902
26	688	261	440	619	778	915	1074
28	812	309	520	723	910	1072	1268
30	946	359	605	833	1051	1249	1477
32	1095	416	701	964	1216	1435	1709
34	1250			1100	1374	1638	1949
36	1412			1243	1552	1850	2200
38	1581			1392	1739	2070	2480
40	1760			1550	1936	2305	2780

[1] Adapted from Purdue Extension Leaflet 273.

[2] Diameter at breast height—4½ feet above ground level.

[3] Length from stump to usable limit in the top.

Appendix C

Extent of the Basic Data

TABLE C-1. Distribution of Study Logs by Diameters and Grades.

Log d.i.b. inches	Log grade				Total	
	Prime	No. 1	No. 2	No. 3	Number	Percent
7				2	2	0.17
8				1	1	0.09
9				13	13	1.13
10			22	26	48	4.18
11			42	37	79	6.88
12			71	40	111	9.66
13			73	47	120	10.44
14		67	38	43	148	12.88
15		66	31	25	122	10.62
16	40	37	24	33	134	11.66
17	23	17	15	26	81	7.05
18	22	11	20	15	68	5.92
19	19	12	10	14	55	4.79
20	23	5	11	10	49	4.27
21	12	6	7	3	28	2.44
22	17	5	10	1	33	2.87
23	11	4	3	5	23	2.00
24	5	3	3	2	13	1.13
25	6	3	2		11	0.96
26	1		1		2	0.17
27	2				2	0.17
28	2	1		1	4	0.35
29						
30						
31						
32	1		1		2	0.17
Total	184	237	384	344	1149	
Percent	16.0	20.6	33.4	30.0		100.00

TABLE C-2. Distribution of Study Logs and Volumes by Species and Log Grades.

	Logs		Mill Scale Volume	
	No.	Percent	Bd. ft.	Percent
By Species				
Ash, white	77	6.7	6,982	4.4
Basswood	47	4.1	5,557	3.5
Beech	149	13.0	27,794	17.5
Cherry	11	1.0	1,032	0.6
Elm, white	134	11.7	15,744	9.9
Hickory	39	3.4	5,595	3.5
Maple, soft	18	1.6	2,149	1.4
Maple, sugar	156	13.6	19,378	12.2
Oak, red and black	332	28.9	49,416	31.1
Oak, white	53	4.6	9,505	6.0
Poplar, yellow	118	10.3	14,158	8.9
Others[1]	15	1.3	1,651	1.0
Total	1149	100.0	158,961	100.0
By Log Grades:				
Prime	184	16.0	42,972	27.0
No. 1	237	20.6	35,428	22.3
No. 2	384	33.4	43,656	27.5
No. 3	344	30.0	36,905	23.2
Total	1149	100.0	158,961	100.0

[1] Includes 4 butternut, 3 black gum, 1 sweet gum, 3 sycamore, and 4 walnut logs.

TABLE C-3. Percentage of Total Volume in Each Log Grade for the Principal Species of Study Logs.

Species	Log Grade				Basis (MBM)
	Prime	No. 1	No. 2	No. 3	
Ash, white	29.4	16.8	31.9	21.9	7.0
Basswood	18.0	17.1	24.0	40.9	5.6
Beech	32.3	14.9	26.2	26.6	27.8
Elm, white	35.6	24.3	32.7	7.4	15.7
Maple, sugar	18.2	28.6	26.8	26.7	19.4
Oak, red and black	28.2	24.7	25.9	21.2	49.4
Oak, white	34.6	3.9	31.8	29.7	9.5
Poplar, yellow	14.1	31.3	29.7	24.9	14.2
All[1]	27.0	22.3	27.5	23.2	159.0

[1] Includes other species as in Table C-2.

Appendix D

Lumber Grade Recovery and Quality Index Data

Table D-1 Percentage lumber grade recovery by log diameters and grades.

Table D-2 Quality indices by log diameters and grades.

Table D-3 Percentage lumber grade recovery by log diameters and species.

Table D-4 Quality indices by log diameters and species.

Table D-5 Percentage lumber grade recovery by species and log grades.

Table D-6 Quality indices by species and log grades.

Table D-7 Quality indices by species, log grades and log diameters.

TABLE D-1. Average (Curved) Percentage Lumber Grade Recovery by Log Diameters and Grades.

Log Grade	Lumber Grade	Log diameter inside bark, in inches											All sizes[1]
		8	10	12	14	16	18	20	22	24	26	28	
Prime	FAS					40	40	40	41	42	45	50	40
	No. 1C					36	35	34	33	34	33	30	34
	No. 2C					14	11	11	11	11	10	11	10
	No. 3C					10	14	15	15	13	12	9	16
No. 1	FAS				18	18	19	21	22	24	27	29	19
	No. 1C				40	42	43	44	47	50	52	55	42
	No. 2C				23	20	18	16	14	11	8	6	19
	No. 3C				19	20	20	19	17	15	13	10	20
No. 2	FAS		6	6	7	8	10	12	14	17	20	24	7
	No. 1C		28	34	38	42	45	47	51	53	57	59	40
	No. 2C		31	30	28	26	23	21	17	14	10	7	27
	No. 3C		35	30	27	24	22	20	18	16	13	10	26
No. 3	FAS	0	1	1	2	3	4	5	6	8	10	13	2
	No. 1C	13	16	21	27	34	41	48	55	58	61	62	28
	No. 2C	42	43	42	39	35	30	25	20	18	16	15	39
	No. 3C	45	40	36	32	28	25	22	19	16	13	10	31
All grades	FAS	1	4	8	13	18	22	25	29	34	39	45	18
	No. 1C	16	22	27	32	46	40	42	43	43	41	39	37
	No. 2C	40	40	36	30	35	19	16	13	10	9	7	24
	No. 3C	43	34	29	25	21	19	17	15	13	11	9	21

[1] Read from graphs of lumber grade recovery at a d.i.b. corresponding to the volume of the average log in each grade.

TABLE D-2. Average Quality Indices by Log Diameters and Grades.

Price relatives: FAS, 1.4; #1C, 1.0; #2C, 0.6; #3C, 0.4

Log d.i.b. (in.)	Log Grade				All grades
	Prime (0)	No. 1 (1)	No. 2 (2)	No. 3 (3)	
			Percent		
7				52	52
8				54	56
9				56	60
10			73	58	63
11			73	60	67
12			73	61	71
13			74	63	74
14		88	74	65	77
15		88	75	67	80
16	103	88	76	70	93
17	103	89	78	72	86
18	104	89	79	74	89
19	104	90	81	77	91
20	104	91	84	80	93
21	104	93	86	83	95
22	105	95	89	87	97
23	105	97	92	90	99
24	106	99	95	94	102
25	106	102	99	98	104
26	107	104	102	102	106
27	108	107	106	106	108
28	110	110	110	110	110
All Sizes[1]	105	90	79	68	. . .

[1] Raw, mean values, uncurved across log grades.

TABLE D-3. Average (Curved) Percentage Lumber Grade Recovery by Log Diameters and Species.

Species	Lumber Grade	Log Diameter Inside Bark in Inches										
		8	10	12	14	16	18	20	22	24	26	28
Ash, White	FAS	1	6	12	20	31	44	58	71			
	No. 1C	14	26	35	39	38	34	28	22			
	No. 2C	38	33	29	25	21	16	11	6			
	No. 3C	47	35	24	16	10	6	3	1			
Basswood	FAS		0	3	6	12	18	27	35	44	54	
	No. 1C		10	23	34	41	44	43	42	39	36	
	No. 2C		73	60	49	38	31	24	18	14	8	
	No. 3C		17	14	11	9	7	6	5	3	2	
Beech	FAS		0	1	1	3	7	11	16	22	27	33
	No. 1C		12	18	26	32	38	44	60	54	57	57
	No. 2C		21	22	22	22	20	17	12	8	5	3
	No. 3C		67	58	51	43	35	28	22	16	11	7
Elm, White	FAS	0	2	8	14	21	28	35	43	50	58	
	No. 1C	0	17	26	32	33	32	30	27	25	21	
	No. 2C	38	30	25	21	19	18	16	14	12	10	
	No. 3C	62	51	41	33	27	22	19	16	13	11	
Hickory	FAS			6	13	18	21	23	24	24		
	No. 1C			20	32	38	40	41	42	42		
	No. 2C			23	28	26	24	23	22	22		
	No. 3C			51	27	18	15	13	12	12		
Maple, Sugar	FAS		1	9	14	17	20	26	34	44	55	
	No. 1C		28	30	34	40	45	46	45	40	31	
	No. 2C		20	20	20	18	14	11	7	4	3	
	No. 3C		51	41	32	25	21	17	14	12	11	
Oak, Black & Red	FAS	1	5	10	16	23	30	34	38	40	41	42
	No. 1C	25	30	34	36	36	36	37	37	37	37	37
	No. 2C	25	25	24	23	21	18	16	13	12	12	12
	No. 3C	49	40	32	25	20	16	13	12	11	10	9
Oak, White	FAS		0	4	9	17	25	32	38	42	44	44
	No. 1C		26	31	36	37	37	39	40	42	45	47
	No. 2C		42	38	33	29	25	20	16	13	9	7
	No. 3C		32	27	22	17	13	9	6	3	2	2
Poplar	FAS	3	4	5	7	8	9	10	12	13	13	
	No. 1C	17	25	32	38	43	47	50	52	55	57	
	No. 2C	56	52	48	44	42	40	38	34	30	28	
	No. 3C	24	19	15	11	7	4	2	2	2	2	

TABLE D-4. Average Quality Indices by Log Diameters and Species.

Price relatives: FAS, 1.4; #1C, 1.0; #2C, 0.6; #3C, 0.4

Species	Log Diameter Inside Bark in Inches										
	8	10	12	14	16	18	20	22	24	26	28
	Percent										
Ash, White	58	68	78	89	99	109	119	130			
Basswood		61	69	77	85	94	102	110	118	126	
Beech		52	56	61	67	73	80	88	95	103	111
Elm, White	45	56	67	78	87	94	100	105	109	113	
Hickory			65	79	85	89	90	91	91		
Maple, Sugar		63	72	79	85	90	94	98	102	106	
Oak, Black & Red	53	64	75	83	91	97	102	106	110	114	117
Oak, white		50	63	75	85	94	101	106	110	113	115
Poplar	57	66	73	78	82	85	88	90	93		

TABLE D-5. Average (Curved) Percentage Lumber Grade Recovery by Species and Log Grades.

Log Grade	Lumber Grade	White Ash	Bass-wood	Beech	White Elm	Hick-ory	Sugar Maple	Red & Bl. Oak	White Oak	Pop-lar	All Species
Prime	FAS	61	52	25	41	13	41	49	62	23	41
	No. 1C	22	34	46	29	41	37	32	21	43	35
	No. 2C	10	13	9	14	25	7	9	6	25	11
	No. 3C	7	1	20	16	21	15	10	11	9	13
No. 1	FAS	26	7	11	27	20	27	27	22	7	21
	No. 1C	44	51	45	30	40	40	43	58	49	42
	No. 2C	17	33	17	18	14	14	12	3	38	18
	No. 3C	13	9	27	25	26	19	18	17	6	19
No. 2	FAS	11	8	6	8	11	15	14	27	8	12
	No. 1C	40	41	45	29	24	44	39	52	32	39
	No. 2C	26	41	14	27	31	16	23	9	49	24
	No. 3C	23	10	35	36	34	25	24	12	11	25
No. 3	FAS	6	6	1	0	2	2	4	3	2	3
	No. 1C	34	35	32	7	31	28	36	46	31	32
	No. 2C	36	45	23	27	42	27	28	30	57	33
	No. 3C	24	14	44	66	25	43	32	21	10	32
All log grades	FAS	27	16	12	24	13	19	25	30	8	20
	No. 1C	34	38	42	27	35	37	37	41	38	37
	No. 2C	22	36	15	20	26	17	18	14	45	21
	No. 3C	17	10	31	29	26	27	20	15	9	22

TABLE D-6. Average Quality Indices by Species and Log Grades.

Price relatives: FAS, 1.4; #1C, 1.0; #2C, 0.6; #3C, 0.4

Species	Log Grades			
	P	1	2	3
	Percent			
Ash	116	96	83	71
Basswood	115	96	81	68
Beech	94	83	73	65
Cherry	97	85	75	66
Elm	103	87	71	56
Hickory	91	83	74	67
Soft Maple	103	85	71	56
Sugar Maple	106	93	81	68
Red (Bl.) Oaks	110	95	82	71
White Oaks	116	101	89	77
Poplar	94	84	77	72
All	105	90	78	68

TABLE D-7. Average Quality Indices by Species, Log Grades and Log Diameters

Price relatives: FAS, 1.4; #1C, 1.0; #2C, 0.6; #3C, 0.4

Species	Log Gr.	Log Diameter										
		8	10	12	14	16	18	20	22	24	26	28
Ash	P					114	118	122	125			
	1				96	100	104	107	110			
	2		71	79	84	88	92	95	97			
	3	51	62	70	75	80	83	87	89			
Basswood	P					103	107	111	115	119		
	1				83	88	93	98	102	106		
	2		66	72	77	82	87	91	95	100		
	3	52	58	64	69	74	79	83	88	93		
Beech	P					81	87	91	95	99	102	105
	1				69	73	78	84	90	95	98	101
	2		55	58	62	66	72	79	85	91	95	97
	3	48	51	54	58	62	66	70	75	80	85	90
Elm	P					105	107	109	110	112	113	
	1				82	88	93	98	102	105	107	
	2		68	69	70	70	72	73	75	78	81	
	3	48	48	49	50	50	50	50	50	50	50	
Hickory	P											
	1					85 all sizes						
	2											
	3					70 all sizes						
Sugar	P					104 all sizes						
Maple	1					93 all sizes						
	2					84 all sizes						
	3					64 all sizes						
Red	P					104	110	114	116	117	118	118
Oak	1				94	96	96	97	97	97	97	97
	2		78	81	83	85	87	89	90	91	92	93
	3	50	56	61	67	73	78	83	87	89	90	91
White	P					114	116	117	118	118	118	
Oak	1				86	92	98	103	108	112	114	
	2		62	70	77	85	92	98	104	109	112	
	3	42	49	56	63	70	76	82	88	93	97	
Poplar	P					96	97	98	98	99		
	1				85	88	90	92	93	94		
	2		71	73	75	77	79	80	81	82		
	3	58	63	67	70	72	75	77	78	80		

Appendix E

Quality Indices Applied to Trees

Table E-1 Derivation of quality indices for hypothetical trees.

Table E-2 Tree quality indices by d.b.h. and tree grade.

Table E-3 Hardwood logging and milling costs.

Table E-4 Relative stumpage conversion surpluses.

Table E-5 Marking guide numbers.

TABLE E-1. Derivation of Quality Indices for Hypothetical Trees[1]

Tree d.b.h.	Log d.i.b.[2]	Log grade	Mill tally volume	Log QI	Tree grade	Tree QI
(in)	(in)	—	(b.f.)	(%)	—	(%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
12	10	3	63	58	3	58.0
12	10	2	63	73	2	73.0
16	12	3	82	61	3	61.0
16	13	2	92	74		
	10	3	63	58		
			155		2.5	67.5
16	13	2	92	74		
	11	2	73	73		
	10	3	63	58		
			228		2.33	69.3
16	14	1	102	88		
	12	2	82	73		
	10	3	63	58		
			247		2	75.4
20	16	2	134	76		
	14	3	102	65		
			236		2.5	71.2
20	16	1	134	88		
	14	2	102	74		
	12	3	82	61		
			318		2	76.5
20	16	1	134	88		
	14	1	102	88		
	12	2	82	73		
			318		1.33	84.1
20	17	0	155	103		
	15	1	118	88		
	13	2	92	74		
	10	3	63	58		
			428		1.5	86.0
20	17	0	155	103		
	15	1	118	88		
	13	2	92	74		
	11	2	73	73		
			438		1.2	87.9
20	16	0	134	103		
	14	1	102	88		
			236		0.5	96.5
20	17	0	155	103		
					0	103.0
24	20	2	228	84		
					2	84.0
24	19	0	202	104		
	16	2	134	76		
			336		1	92.8
24	20	0	228	104		
	17	1	155	89		
	14	2	102	74		
			485		1	92.9
24	20	0	228	104		
	18	0	176	104		
	16	1	134	88		
	13	3	92	63		
			630		1	94.6
24	20	0	228	104		
	18	0	176	104		
	16	2	134	76		
	14	2	102	74		
	11	3	73	60		
			713		1.4	89.9
24	20	0	228	104		
	18	0	176	104		
	16	1	134	88		
	14	1	102	88		
			640		0.5	98.1

[1] Column Sources

1, 2 and 3 assumed.

4 read from Table B-2 for 12-foot logs.

5 read from Table D-2.

6 from Column 3, see page 9.

7 mean of Column 5 weighted by Column 4.

[2] All logs are 12 feet long.

TABLE E-2. Average Tree Quality Indices.

Tree d.b.h. (in.)	Tree Grade—Unweighted average of log grades												
	0	⅓	½	⅔	1	1⅓	1½	1⅔	2	2⅓	2½	2⅔	3
	Percent												
12									73	68	65	63	58
13									73	68	66	63	59
14									74	69	66	64	59
15									74	69	67	65	60
16					88	84	81	79	75	70	68	65	61
17					89	84	82	80	75	71	68	66	62
18	102	98	96	94	89	84	82	80	76	72	69	67	63
19	103	98	96	94	90	85	83	81	77	72	70	68	64
20	103	99	96	94	90	86	84	82	77	73	71	69	65
21	103	99	97	95	91	86	84	82	78	74	72	70	66
22	103	99	97	95	91	87	85	83	79	75	73	71	67
23	104	100	98	96	92	88	86	84	80	76	74	73	69
24	104	100	98	96	93	89	87	85	82	78	76	74	71
25	104	101	99	97	94	90	89	87	83	80	78	76	73
26	104	101	100	98	95	92	90	88	85	82	80	79	76
27	105	102	100	99	96	93	92	90	88	86	84	83	80
28	105	103	101	100	98	96	94	93	92	90	89	88	86
29	106	104	102	101	99	98	98	97	96	95	95	94	93
30	106	105	104	103	101	101	101	101	101	101	101	101	101

TABLE E-3. Absolute and Relative Costs of Hardwood Logging and Milling.

d.b.h. (in.)	Absolute[1] cost per M	Relative cost	
		raw	curved
	($)	(%)	(%)
12			84.3
13			77.3
14	53.53	70.6	70.8
15			65.1
16	45.48	60.0	60.0
17			55.8
18	40.21	53.0	52.6
19			49.8
20	35.74	47.2	47.4
21			45.3
22	32.88	43.4	43.4
23			41.9
24	30.78	40.6	40.6
25			39.2
26	28.84	38.0	38.0
27			37.1
28	27.54	36.3	36.3
29			35.5
30	26.56	35.0	34.9

[1] From Shames (James) (1946), Table 11, Note 65.

TABLE E-4. Relative Stumpage Conversion Surpluses.[1] (in Percent of No. 1C Lumber Price)

Tree d.b.h. (D)	0	⅓	½	⅔	1	1⅓	1½	1⅔	2	2⅓	2½	2⅔	3
	Conversion Surplus in Percent												
11									−19.4	−24.5	−27.0	−29.7	−34.0
12									−11.5	−16.5	−18.9	−21.6	−26.3
13									−4.1	−9.0	−11.4	−14.0	−18.6
14									2.9	−2.0	−4.3	−6.9	−11.4
15									9.1	4.3	1.9	−0.5	−4.9
16					28.2	23.5	21.3	18.9	14.8	10.0	7.7	5.4	1.0
17					32.6	28.1	26.0	23.7	19.5	14.9	12.6	10.4	6.0
18	49.9	45.6	43.2	41.0	36.4	31.9	29.8	27.5	23.4	18.9	16.6	14.4	10.1
19	52.9	48.6	46.2	44.1	39.7	35.3	33.2	31.0	26.9	22.4	20.2	18.2	14.0
20	55.5	51.2	49.1	47.0	42.6	38.4	36.3	34.1	30.0	25.6	23.5	21.6	17.4
21	57.8	53.6	51.5	49.5	45.4	41.1	39.0	37.0	33.0	28.7	26.5	24.7	20.7
22	59.9	55.9	53.9	51.9	47.9	43.8	41.8	39.8	35.9	31.7	29.8	27.8	24.0
23	61.6	57.8	55.9	54.0	50.1	46.2	44.2	42.4	38.5	34.6	32.6	30.7	27.2
24	63.2	59.6	57.8	55.8	52.3	48.5	46.6	44.8	41.1	37.6	35.6	33.6	30.4
25	64.9	61.5	59.7	57.9	54.6	51.1	49.4	47.7	44.1	40.7	38.8	36.9	33.9
26	66.4	63.3	61.6	60.0	56.8	53.8	52.1	50.2	47.3	44.2	42.5	40.8	38.0
27	67.7	64.8	63.3	61.8	58.9	56.3	54.7	53.4	51.0	48.6	47.1	45.6	43.2
28	68.8	66.4	65.1	63.7	61.2	59.3	58.1	57.0	55.5	53.9	52.9	51.5	49.6
29	70.0	68.1	67.0	65.9	63.7	62.8	62.1	61.4	60.7	59.8	59.3	58.5	57.2
30	71.1	69.8	68.9	68.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1

[1] Tree quality index values reduced by a standard differential cost trend pegged at 60% at the 16-inch d.b.h., i.e., stumpage plus margin for profit and risk.

These values are well defined, within the indicated limits, by the following empirical formulas—

Tree grade

0 $S = -84.02 + 13.23(D) - 0.4016(D^2) + 0.004427(D^3)$. — 18″ to 30″—

1 $S = -150.13 + 20.25(D) - 0.7228(D^2) + 0.009598(D^3)$. — 16″ to 30″—

2 $S = -230.90 + 30.68(D) - 1.2597(D^2) + 0.018904(D^3)$. — 12″ to 30″—

3 $S = -273.39 + 35.52(D) - 1.5361(D^2) + 0.024306(D^3)$. — 12″ to 30″—

TABLE E-5. Marking Guide Numbers. (Increments in Conversion Surplus per inch of d.b.h.)

d.b.h. (in.)	Tree Grade			
	0	1	2	3
10			−15	−42
12			42	2
14			114	72
16		214	170	125
18	306	259	211	168
20	379	334	278	226
22	400	364	322	291
24	461	438	419	391
26	502	504	566	621
28	552	617	817	989
30	614	792	1160	1503

Species Value Factors (Appalachian Market, April 10, 1954)[1]

Hickory	0.6
Beech	0.8
Ash, soft maple	0.85
Red, white oak	0.9
Basswood	0.95
Hard maple, yellow poplar	1.0
Cherry	1.1
Black walnut	1.3

[1] Hardwood Market Report (1954).

Literature Cited

Beazley, R. I. and A. M. Herrick, 1954. Lumber price relatives: their application in the hardwood quality index. Purdue A.E.S. Bull. 610.

Betts, H. S. and R. K. Helphenstine, 1920, rev. 1933. How lumber is graded. U.S.D.A. Dept. Circular No. 64, Washington, D. C.

Burkle, J. L. and Sam Guttenberg, 1952. Marking guides for oaks and yellow poplar in the southern uplands. U.S.D.A., Sou. For. Exp. Sta., Occ. Paper 125.

Campbell, R. A., 1951. Tree grades, yields and values for some Appalachian hardwoods. U.S.D.A., Southeastern For. Expt. Sta., Sta. Paper No. 9.

_____, 1955. Tree grades and economic maturity for some Appalachian hardwoods. U.S.D.A., Southeastern For. Expt. Sta., St. Paper No. 53.

Cummings, W. H. and T. G. Zarger, 1953. Guide for improved forest management for sawtimber from the major hardwoods in the Tennessee Valley, T.V.A., Div. of For. Relations, Report No. 209-53.

Ellertson, B. W. and P. Lane, 1953. Lumber price ratios for computing quality index of Tennessee Valley hardwoods. T.V.A., Division of For. Relations, Tech. Note. No. 15.

Guttenberg, Sam and W. A. Duerr, 1949. A guide to profitable tree utilization, U.S.D.A., Sou. For. Exp. Sta., Occ. Paper 114.

_____ and J. A. Putnam, 1951. Financial maturity of bottomland red oaks and sweetgum. U.S.D.A., Sou. For. Exp. Sta., Occ. Paper 117.

_____ and R. R. Reynolds, 1953. Cutting financially mature loblolly and shortleaf pine. U.S.D.A., Sou. For. Exp. Sta., Occ. Paper 129.

Hardwood Market Report, 1954. Published weekly at Memphis, Tennessee.

Herrick, A. M., 1939, rev. 1948. A field manual for forest mensuration, Purdue Univ. 129 pp. processed.

_____, 1945. A numerical evaluation of stand structure. Jour. Forestry 43:891.

_____, 1946(a). Grade yields and overrun from Indiana hardwood sawlogs. Purdue A.E.S. Bull. 516.

_____, 1946(b). Composite volume tables for Indiana hardwoods. Purdue Univ. Ext. Leaflet 273.

_____, 1949. How to grade hardwood sawlogs. Purdue Univ. Ext. Bull. 346.

Martinelli, Mario, 1948. The conversion of flat-rate stumpage value to specific rate for individual tree grade. Jour. Forestry, 46:843.

McCoy, E. W., 1952. An analytical comparison of grade yields and overrun in Indiana hardwood sawlogs. Unpublished Master's thesis on file at Purdue University.

Mesavage, C. and J. W. Girard, 1946. Tables for estimating board-foot volume of timber, U.S.D.A., Forest Service. Unnumbered.

Purdue University, 1953. Proceedings of a symposium on a standard quality index for hardwoods. Purdue A. E. S.

Shames (James), L. M., 1946. Logging and milling studies in the Southern Appalachian regions. U.S.D.A., Southeastern For. Exp. Sta., Tech. Note 65.

Society of American Foresters, 1950. Forestry Terminology, Soc. of Amer. For., Washington 6, D. C.

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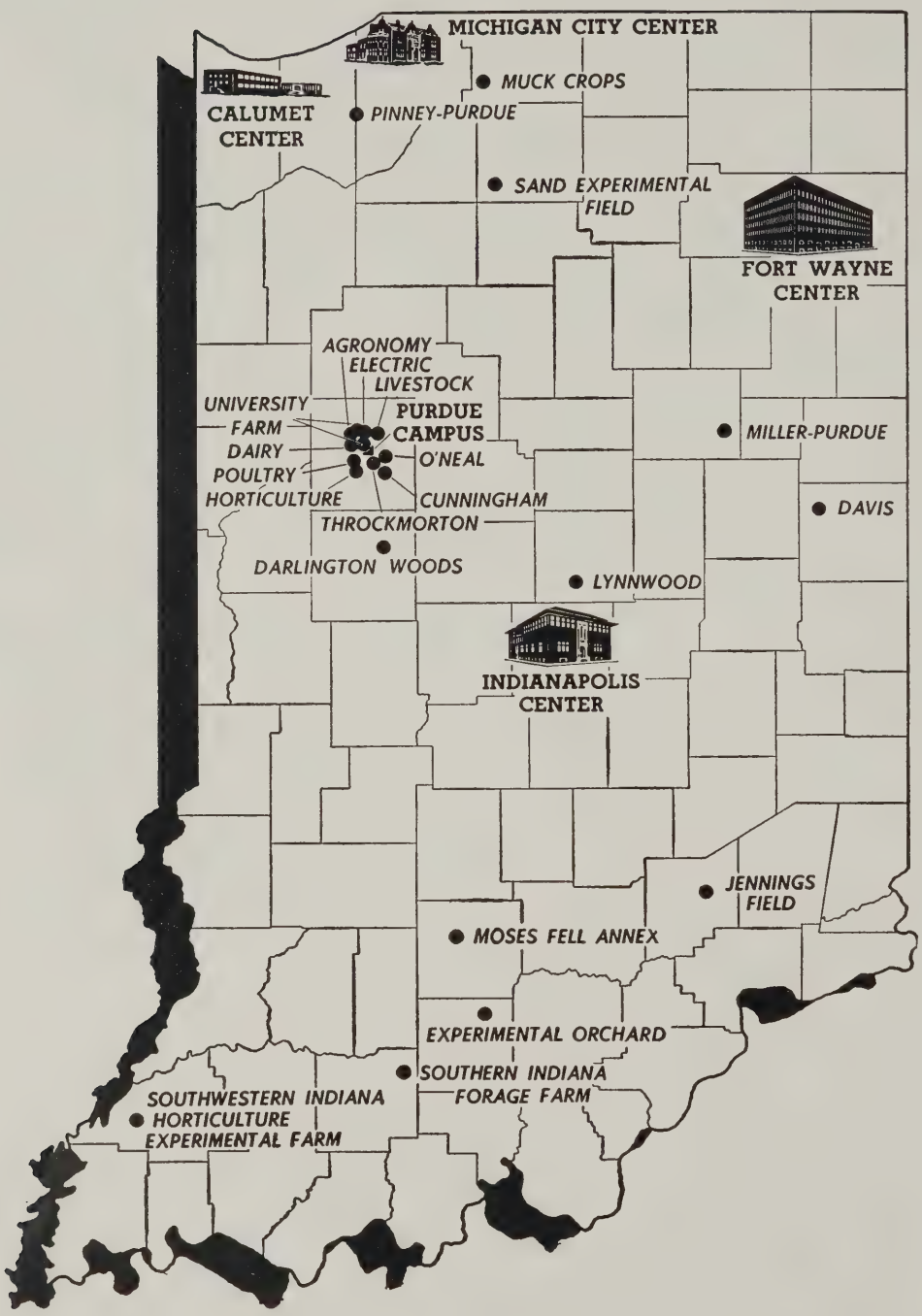

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